Improving access to and use of ocean observations from animal borne sensors project TOPP-ONR-IOOS

Barbara Block
Stanford University
Hopkins Marine Station
120 Ocean View Blvd
Pacific Grove, CA 93950-3024
phone: (831) 655-6236 fax: (831) 375-0793 email: bblock@stanford.edu

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SUMMARY

Stanford University's Tagging of Pelagic Predators (TOPP) program – a project of the Census of Marine Life - at the Hopkins Marine Lab in Pacific Grove, CA working with the U.S. IOOS Program (IOOS) of the National Oceanic and Atmospheric Administration and the U.S. Navy's Office of Naval Research (ONR) Marine Mammals and Biological Oceanography Program (MMB) facilitated improved access and use of associated ocean observing data, particularly physical oceanographic data, by ocean modelers from the Naval Oceanographic Office (NAVOCEANO) and at the National Centers for Environmental Prediction of NOAA's National Weather Service (NOAA/NCEP). Technical staff at IOOS and ONR have been worked with scientists and computer programmers at TOPP to implement web-based data services and other community-based software tools and technologies that can enable broader exposure of TOPP animal tagging data sets based on customer requirements for data representation, metadata, QA/QC, format and delivery. The project is being conducted over a 6 month period. Funds have been received from NOAA/US IOOS to support this activity. Additional supporting funds were provided by ONR/MMB.

PROJECT DESCRIPTION

To demonstrate the benefit of animal telemetry observations and transition of the animal telemetry technology to operational status, U.S. IOOS Program (IOOS) of the National Oceanic and Atmospheric Administration and the U.S. Navy's Office of Naval Research (ONR) Marine Mammals and Biological Oceanography Program working in collaboration with Stanford University's Tagging of Pelagic Predators (TOPP) program initiated a 6 months project in 2011 with the goal to facilitate improved access and use of associated ocean observing data, particularly physical oceanographic data, by ocean modelers and other scientists. Scientists and computer programmers at TOPP worked with technical staff at IOOS and ONR to implement web-based data services and other community-based software tools and technologies that enabled exposure of TOPP animal tagging data sets to ocean modelers from US NAVY and NOAA.

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BACKGROUND

TOPP began in 2000 as one of 17 projects of the Census of Marine Life, an ambitious 10-year, 80-nation endeavor to assess and explain the diversity and abundance of life in the oceans, and where that life has lived, is living, and will live. Several dozen TOPP researchers from eight countries began venturing into offshore waters, remote islands, and along rugged coastlines to attach satellite tags to 22 different species of top predators that roam the Pacific Ocean. As of 2011, they have tagged more than 4,500 animals, including elephant seals, bluefin tunas, yellowfin tunas, white sharks, whales, leatherback turtles, squid, albatross and sooty shearwaters.

U.S. IOOS is a coordinated network of people and technology that work together to generate and disseminate continuous observing data, information, models, products and services for U.S. coastal waters, ecosystems, Greats Lakes and oceans. Most of the ocean observations data collected and distributed by IOOS are physical measurements of ocean features and characteristics (water temperature, wave height/direction, circulation, salinity, etc.). Two recently emerging areas of focus for IOOS are improved access to ocean measurements by modelers using a suite of community-based tools and protocols and enabling broader access to and use of biological observations using a very similar suite of enabling tools.

The Office of Naval Research (ONR) Marine Mammals and Biological Oceanography Program (MMB), which supports basic and applied research on a wide range of topics related to oceanic biota – ranging from the largest whales to the fish, zooplankton, phytoplankton and benthos, is also interested in supporting efforts to provide broader access to TOPP date, particularly to enable stronger coupling of biological and physical data to better understand and predict animal distribution in the ocean. The MMB program has a long history of sensor and tag development. The program is guided by, though not limited to, research and technology development related to (1) understanding the effects of sound on marine mammals, including physiological, behavioral, and ecological effects and (2) the interactions between biota and sound or light in the ocean. The largest investments in this program focus on marine mammals. Our current program thrusts include, but are not limited to: Monitoring & Detection, Integrated Ecosystem Research, Hearing & Physiological Effects of Sound, Sensor & Tag Development, Controlled Exposure Experiments, Models & Databases for Environmental Compliance, Physiology, Population Level Effects of Sound Exposure.

PROJECT GOALS & OBJECTIVES

The goal was to demonstrate the application of IOOS-based data interoperability tools and technologies for achieving broader exposure and use of ocean observations data collected from animal borne sensors. It is anticipated that this will help improve:

- Forecasting of ocean conditions, particularly is sparsely sampled regions;

The project objectives were to:

a) Document customer-based requirements for improved access to TOPP data, particularly physical oceanographic data collected from elephant seals and sharks for use by an ocean modeling customer through interviews of modeling customers at NAVO and NCEP.

b) Evaluate means to meet customer requirements using existing community tools and technologies for data access, representation, and distribution through meetings with technical

team to develop technical solutions based on customer requirements and based on existing IOOS tools and data services.

c) Implement at TOPP a new data service and protocol that meets the ocean modeling customer requirements.

d) Complete a plan describing additional future opportunities to expand the initial TOPP-IOOS-ONR partnership to additional customers/applications.

Milestones/Schedule

a. Identify and interview initial ocean modeling customer and document requirements for access to TOPP oceanographic data from elephant seals carrying SMRU (temperature only and CTD tags) and ARGOS tags, sharks with MK10 PAT tags (Month 1)
b. Design a candidate solution for customer requirements based on publicly available, open source tools and technologies (Month 2)
c. Implement initial or "beta" version of appropriate data services/protocols (Month 3)
d. Test, evaluate and revise "beta" version in close collaboration with initial customer (Month 3)
e. Implement final version of customer-based data services (Month 4)
f. Identify candidate additional customer(s) or consumers of TOPP data – if resources allow – and conduct requirements analyses per access to TOPP data (Month 4)
g. Implement beta phase of next round of data services – test and revise in collaboration with customer(s) (Month 5)
h. Draft initial project report documenting all activities and including recommendations for next steps and additional customer engagements (Month 5)
i. Finalize project report. (Month 6)

Deliverables/products

a. Initial data services for delivery of TOPP elephant seals SMRU temperature-only and CTD data, and sharks MK10 PAT tag data to ocean modeling customer.
b. Additional, if resources allow, data services for one or more additional customers or consumers of TOPP ocean observations.
c. Project report including detailed documentation on products and services developed and recommended priorities for next steps in enabling broader access to TOPP data and possibly other similar marine animal tagging programs.

ID	Outline Number	Task Name	Duration	Start	Finish	% Complete	Lead
1	1	**Phase I- Document customer-requirements**	**35 days**	**Mon 11/14/11**	**Fri 12/30/11**	**0%**	
2	1.1	Conduct Interviews	35 days	Mon 11/14/11	Fri 12/30/11	0%	
3	1.2	Draft customers requirements	35 days	Mon 11/14/11	Fri 12/30/11	0%	
4	2	**Phase II-Design a candidate solution to meet customer requirements**	**38 days**	**Mon 1/9/12**	**Wed 2/29/12**	**0%**	
5	2.1	Consult with TOPP-ONR and IOOS technical teams and evaluate the services at TOPP	38 days	Mon 1/9/12	Wed 2/29/12	0%	
6	2.2	Design system concept to represent and access the Animal telemetry data (Physical Oceanographic data)	38 days	Mon 1/9/12	Wed 2/29/12	0%	
7	2.3	Publish system concept document	38 days	Mon 1/9/12	Wed 2/29/12	0%	
8	3	**Phase III- Implementation of data services and protocols**	**66 days**	**Thu 3/1/12**	**Thu 5/31/12**	**0%**	
9	3.1	Select/integrate datasets	11 days	Thu 3/1/12	Thu 3/15/12	0%	
10	3.2	Deploy webservices to access the data	56 days	Thu 3/15/12	Thu 5/31/12	0%	
11	3.3	Connect to user application	23 days	Tue 5/1/12	Thu 5/31/12	0%	
12	4	**Phase IV-Testing/Evaluation**	**44 days**	**Tue 5/1/12**	**Fri 6/29/12**	**0%**	
13	4.1	Test, and revise "beta" version in collaboration with customers	23 days	Tue 5/1/12	Thu 5/31/12	0%	
14	4.2	Evaluation report	21 days	Fri 6/1/12	Fri 6/29/12	0%	
15	5	**Phase V- Develop Next Plans**	**21 days**	**Mon 7/2/12**	**Mon 7/30/12**	**0%**	
16	5.1	Identify candidate additional customer (s) of TOPP data	21 days	Mon 7/2/12	Mon 7/30/12	0%	
17	5.2	Implement beta phase of next round of data services- test and revise in collaboration with the customers	21 days	Mon 7/2/12	Mon 7/30/12	0%	
18	5.3	Document initial project report documenting all activities and including recommendations next steps and additional customer requirements	21 days	Mon 7/2/12	Mon 7/30/12	0%	
19	5.4	Finalize Project Report	21 days	Mon 7/2/12	Mon 7/30/12	0%	

Project: TOPP-ONR_IOOS_ GANTT-N
Date: Wed 7/25/12

Task, Split, Summary, Project Summary, External Tasks, External Milestone, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, Progress, Deadline

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Figure 1: Project Gantt chart

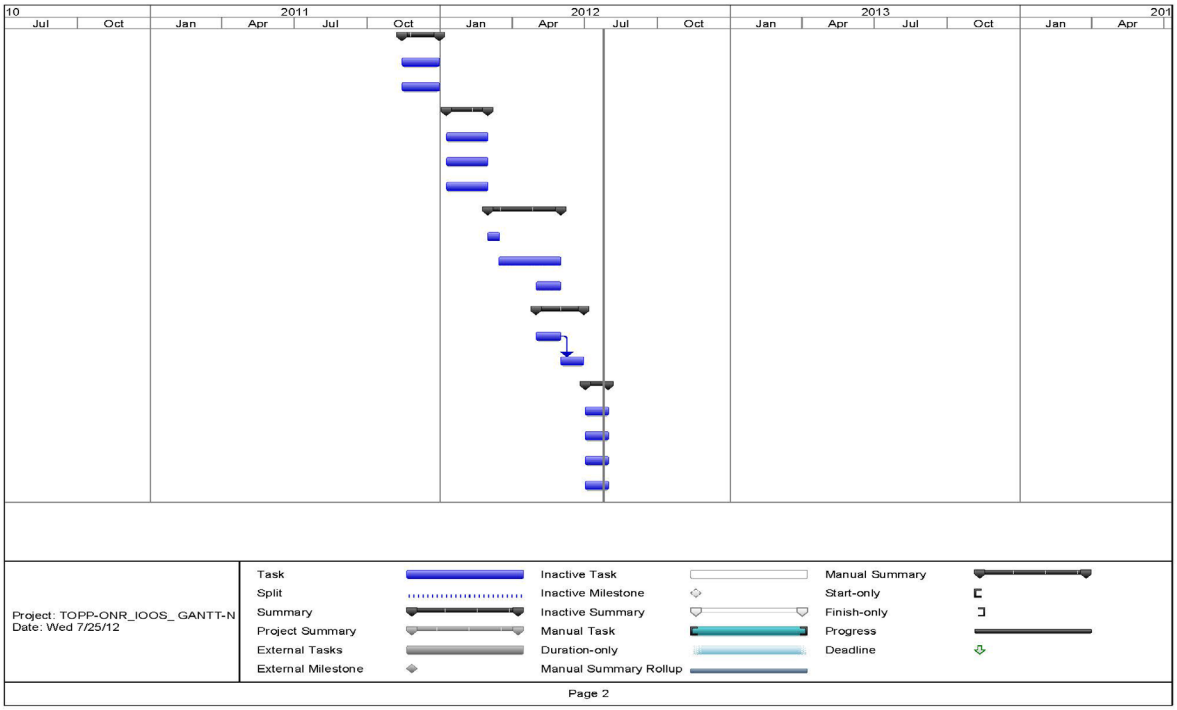

Figure 2. Milestones and schedule

ACCOMPLISHMENTS

An initial kickoff meeting was held on November 4 to discuss the objectives of the project, and to plan activities for its successful completion. Several conference calls were held on a monthly basis to update progress with all stakeholders, and to discuss upcoming issues.

In late January a secure, geospatially-enabled database was established at Hopkins Marine Station of Stanford University to ingest, store and serve relevant, animal-derived oceanographic data to NOAA. An ERDDAP server system was installed on the server to enable users to perform queries of the data, and to facilitate rapid delivery of data products in a variety of standard oceanographic formats.

A total of 57 datasets, from northern elephant seals, have been ingested into the database. A total of approximately 350 elephant seal datasets have been provided by the Costa Lab at UC Santa Cruz and are currently being ingested into the database.

In addition to populating the database with sample elephant seal data, the Stanford team worked closely with NOAA colleagues to standardize the nomenclature used in the data system, and to create a standard metadata format to accompany all animal-derived datasets, which is both informative and useful.

In late February, two elephant seals were tagged in Año Nuevo with special tags that provide real-time CTD uplinks. Working with colleagues at ONR, the Stanford team developed a custom script which delivered this near-real-time data in MOODS format (not provided by the ERDDAP server itself). This exercise served as a proof-of-concept that it would be possible to deliver oceanographic data in near-real time. In May the two CTD tags that were deployed on elephant seals in February 2012 were recovered by the UCSC field team and these same two tags were redeployed on two different female elephant seals in early June 2012. These tags are currently providing real-time CTD data through the TOPP server. This shows that the Animal telemetry is operational and can contribute to augmenting observing data access by modelers.

Accessing Data in ERDDAP

Top level of ERDDAP server:
http://dataxfer.stanford.edu:8080/erddap/index.html
Get a list of all tags (event id's) - change ".htmlTable" to ".csv" if you want:
http://dataxfer.stanford.edu:8080/erddap/tabledap/xfertestONR.htmlTable?event_id&distinct()&orderBy("event_id")
Temperature at 10m along the track of tag 297 (you can change the event id in the URL to any that you got in the above request):
http://dataxfer.stanford.edu:8080/erddap/tabledap/xfertestONR.png?longitude,latitude,temperature&event_id=297&altitude=-10&.draw=markers&.marker=5|5&.color=0x000000&.colorBar=|||||
Same as above but for depths of about 200m:
http://dataxfer.stanford.edu:8080/erddap/tabledap/xfertestONR.png?longitude,latitude,temperature&event_id=297&altitude=~%22-200%22&.draw=markers&.marker=5|5&.color=0x000000&.colorBar=|||||
Graph of profile depths for tag 297 for October 2004 vs time and longitude (change time as desired):

http://dataxfer.stanford.edu:8080/erddap/tabledap/xfertestONR.graph?time,altitude,temperature&event_id=297&time%3E=2004-10-01T00:00:00Z&time%3C=2004-11-11T00:00:00Z&.draw=markers&.marker=3|5&.color=0x000000&.colorBar=|||||
Download all the data for tag 297 as a netcdf file (or use this URL within Matlab or Ferret) (or change ".nc" to another file type):
http://dataxfer.stanford.edu:8080/erddap/tabledap/xfertestONR.nc?time,latitude,longitude,temperature,altitude&event_id=297
Query data are entered into these fields

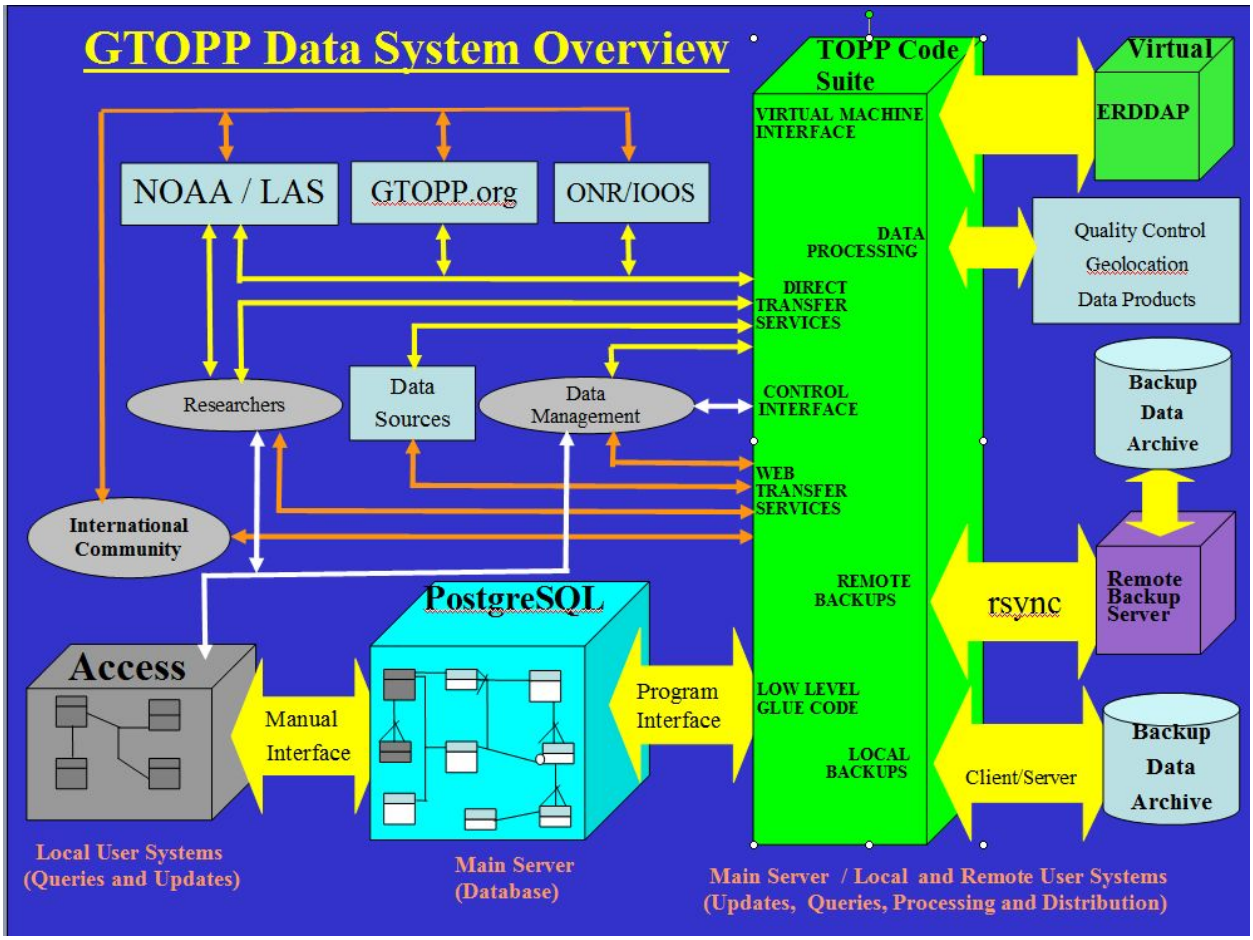

FIGURE 3. Overview of GTOPP data system

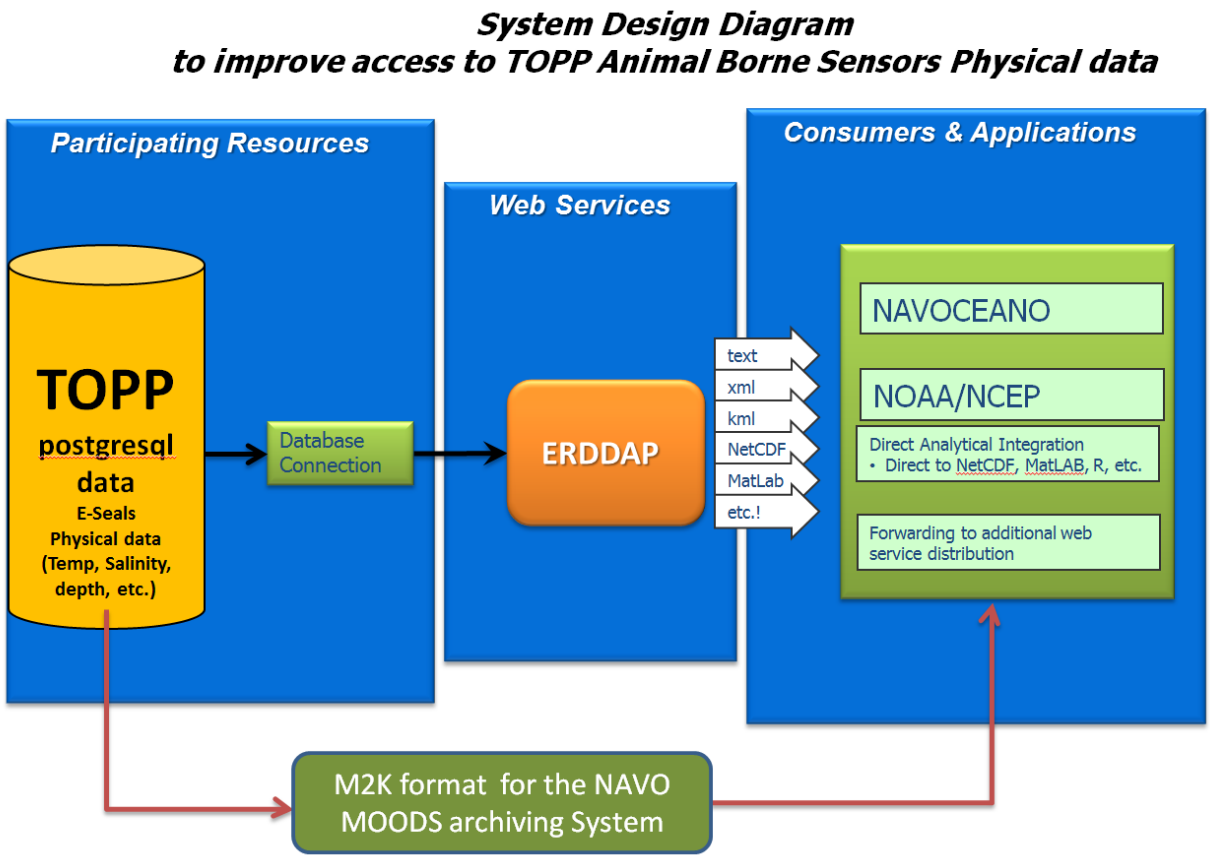

Figure 4. System design diagram

RECOMMENDATIONS FOR NEXT STEPS

The goals of this project were to build a system whereby animal-derived oceanographic data could be delivered to users in a format consistent with existing IOOS systems, standards and protocols; and to demonstrate the value of these data to the oceanographic community that rely upon these systems. Having succeeded in these goals, the next step is to expand this effort to include more, different species of animal-borne sensors in the IOOS system, across a broader geographic range. There is broad support for such an effort, and discussions are ongoing about creating a national "Animal Tracking Network" (ATN), which would serve to integrate animal telemetry studies with IOOS in a coordinated, consistent way. By developing, maintaining and disseminating an integrated data management system, consisting of animal telemetry data gathered by private, academic, local, state and federal institutions, IOOS will gain the capacity to lead and strengthen our national ocean observing capabilities in this area. This approach will augment our existing knowledge and understanding of ocean ecosystems and our ability to engage in science-based decision making and ecosystem-based management.

The following are recommendations on how IOOS can integrate ATN efforts into national and international systems for delivering critical information on biological resources and ecosystem function, and deliver oceanographic data that can compliment and enhance existing observing capability. We envision the role for organizing ATN would be as follows:

1. Invest, deploy and maintain key assets (tags, underwater receivers and data management systems) required for building a national ATN across the nation's waters.
2. Improve the national ATN data management capacity by establishing standards and infrastructure for facilitating this IOOS activity.
3. Synthesize and make animal telemetry products available to advance the NOP Priority Objectives (i.e. Ecosystem-based Management, Coastal and Marine Spatial Planning)
4. Advance the National capacity for making animal oceanographic telemetry data accessible in near-real-time via Global Telecommunications System (GTS).
5. Establish the capacity to assimilate ATN data daily to the ocean modeling community (HYCOM, ROMS).
6. Establish pathways for rapid sharing and maintaining data at National and International levels. This will help avoid duplication of ATN efforts and ensure data are compatible and accessible for analyses and assimilation by computer models. Increased access to animal telemetry information will improve our ability to provide accurate forecasts and inform ecosystem based coastal and marine spatial planning.
7. Promote development of new and lower cost tag technology.
8. Promote investment in new sensors (e.g. oxygen and pH sensors) in response to growing concerns about the potential impacts of ocean acidification and hypoxia on marine biological resources and the health of marine ecosystems.
9. Bring permanence and sustainability to a national network. ATN will only be successful with a sustained long-term support for maintenance of infrastructure for receiving data (such as acoustic receiver arrays), regional support at RAs for tag deployment (e.g. animal borne sensors on all three coasts), and for advancement of technology to continue providing continuous biological and geophysical observations.
10. Discern how best to reduce costs of deployments (e.g. by coordinating deployments on existing monitoring missions by federal or state vessels).
11. Document and coordinate priority deployment of animal telemetry assets. Currently, there is a diverse set of animal telemetry projects taking place throughout the country with different Federal, state, academic or regional objectives.
12. Expand animal telemetry outreach and education programs. Animals are a way to foster a public understanding of the value of the ocean, coasts and the ocean observing systems. Resources and funding should be given to support building products for grades K-12 with animal and telemetry data. Aquariums offer great opportunities to expose the public to this initiative through education programs and by exhibiting tracks of tagged animals in near-real time.
13. Plan and execute demonstration projects in 2013 that demonstrate one or more of the above recommendations.

TESTIMONIALS

From NAVOCEANO
Dr. Frank Bub
Ocean Modeling Technical Lead (NP3M)
Naval Oceanographic Office

The IOOS/ONR-sponsored Marine Mammal Observation Project looks to be an excellent success. Interactions with the Naval Oceanographic Office (NAVOCEANO) and NOAA's Environmental Prediction Center (EPC) have led to an acceptable formatting for insertion of historical data into our archives and we anticipate the delivery of large data sets from over ten years of elephant seal observations. In addition, the insertion of real-time data into the Global Telecommunications System (GTS) will be of great benefit to real-time modeling at NAVOCEANO and EPC. These observations appear to be of excellent quality and the animals are sampling regions of the ocean that are generally under-observed. After quality-control, marine mammal observations are assimilated, adjusting the initial ocean fields toward "reality."

The data appear beautiful. All passed our QC. No profiles have temperature or salinity spikes and there are no disagreements with either Levitus or GDEM climatology (within our prescribed tolerances).

We will work up some profile and location displays later. Note that comparisons with model fields may be somewhat rudimentary. Our current operational models started in fall 2008-- I'll see what can be done. As I've indicated, NAVOCEANO works mostly in "real-time" but NRL may have some comparison capabilities that can be applied.

Bottom line: it appears you have achieved the objective of this project-- deliver collected marine mammal observations from the TOPP program to operational centers. I will talk with Dick Crout about transferring these data to NODC where they will be available to the world.

In addition, Stanford has set up real-time delivery of the data via ERDDAP and GTS and we are receiving these observations for model assimilation. This is what we call "lagniappe" here on the Gulf Coast-- an extra pleasant surprise.

Frank

From University of California, Santa Cruz (update)
Dr. Dan Costa
Professor of Ecology and Evolutionary Biology
UC Santa Cruz
Hi:
As an update. The two tags were redeployed a week ago. The two elephant seals had returned to the beach and the tags recovered. The tags were redeployed on June 10. At least one of the females left the same day the other one should be at sea by now. So there should be real time data available now from these two tags.

Best,

Dan